LAND USE EFFECTS ON SOIL QUALITY PARAMETERS FOR IDENTICAL SOIL TAXA

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ABSTRACT

Near-surface or use-dependent soil properties are relatively dynamic and can change over a few years time. These manageable, use-dependent properties are critical to soil quality. Past studies have documented land use effects on near-surface soil properties without ensuring soil taxa were identical. Our objective was to evaluate soil quality differences due to land use in taxonomically identical soils. Research sites were located at the Sand Mountain Research Center (SMRC) and E.V. Smith Research Center (EVS) of the Alabama Agricultural Experiment Stations. Soils were classified as fine-loamy, siliceous, subactive thermic Typic Hapludults at SMRC and coarse-loamy, siliceous, subactive, thermic Typic Paleudults at EVS. Experiments were conducted in long term conventional and conservation tillage plots, pastureland, and woodland areas. Investigated parameters included: bulk density (Db), water stable aggregates (WSA), saturated hydraulic conductivity (Ksat), soil water retention (SWR), soil strength, water dispersible clay (WDC), soil organic carbon (SOC), total nitrogen (TN), and soil microbial biomass C. Results at SMRC indicated that the conventional tillage system had lower values of WSA, SWR, SOC, TN, and soil microbial biomass C as compared to the other systems. At SMRC, WSA in the conventional tillage system were 28, 25, and 24% lower than pastureland, woodland, and the conservation tillage system, respectively. Similarly, SWR in the conventional tillage system was 19, 23, and 11% lower than pastureland, woodland, and the conservation tillage system, respectively. Pastureland had higher WSA, Db, and soil strength. Woodland had the highest SOC, TN, microbial biomass C, and Ksat. At EVS, the conventional and no-tillage systems had lower WSA, WDC, and microbial biomass C and higher Db and SWR compared to woodland. Pastureland had higher SWR, SOC, TN, and soil microbial biomass C than woodland. The conservation tillage system had higher WSA, SWR, TOC, TN, and microbial biomass C and lower Ksat, and WDC compared to the conventional tillage system. At EVS, WSA in the conventional tillage system were 14, 26, and 12% lower than pastureland, woodland, and the conservation tillage system, respectively. In addition, the woodland had lower values of SOC and TN compared to the pastureland and conservation tillage systems. Our data at EVS suggests that loblolly pine (*Pinus teada* L.) plantation management did not improve soil quality relative to croplands. In general, the aggregate of data suggested that intensive soil cultivation resulted in reduced soil quality at both sites. Our data showed differences in near-surface soil properties that resulted from land use systems in taxonomically similar soils. Variation in near-surface properties resulting from land use suggests further work is needed to enhance soil map unit interpretations.

KEYWORDS

Soil quality, land use, soil taxa, use-depedent soil properties, soil.

INTRODUCTION

Knowledge of the land use impacts on soil quality is necessary for sustainable agricultural production. Sustainability is related to soil quality, which is defined as, "the capacity of a specific kind of soil to function, within natural or managed boundaries, to sustain plant and animal productivity, maintain or enhance air and water quality, and support human health and habitation" (Karlen, 1997). The soil's ability to function as a component of an ecosystem may be degraded, aggraded, or sustained as use-dependent properties change in response to land use and management. For example, conservation tillage practices generally result in higher amounts of soil organic matter (SOM), reduced erosion, increased infiltration, increased water stable aggregates, and greater microbial biomass C when compared to conventional tillage systems (Reeves, 1997). Some studies have shown that when woodland is converted to

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pastureland, soils are subject to compaction and subsequently decreased porosity (Deuchare *et al.,* 1999). Conversely, when pasture is converted to woodland, infiltration increases with increasing forest age (Carter *et al*., 1998).

Soil taxonomy emphasizes subsurface properties and de-emphasizes near-surface soil properties because of their dynamic nature. The dynamic nature of near-surface soil properties requires the evaluation of land use effects on soil systems for better characterization of soil map units. Near-surface soil properties impact many soil interpretations, thus it is essential to understand the variability of use-dependent soil properties in taxonomically similar soils. Our main objectives were to: 1) evaluate land use effects on soil chemical, physical, and biological properties in taxonomically identical soils to assess soil quality, and 2) define ranges in near-surface soil properties impacted by variation in soil management strategies.

MATERIALS AND METHODS

Study Sites

The study sites were located in two physiographic regions of the Southeastern USA. Sand Mountain Research Center (SMRC) is located near Crossville, AL, and E. V. Smith Research Unit (EVS) is located near Shorter, AL. Soil laboratory characterization was conducted to ensure soils were taxonomically similar. Soils at SMRC are located on the Appalachian plateau, are formed over sandstone, and classified as fine-loamy, siliceous, subactive, thermic Typic Hapludults. Soils at EVS are located in the Coastal Plain, are formed from fluvial sediments, and classified as coarse-loamy, siliceous, subactive, thermic Typic Paleudults.

At the SMRC site, tillage experiments have been established for 12 years with treatments consisting of rotational cropping-no tillage, continuous cropping-no tillage, rotational cropping-conventional tillage, and continuous cropping-conventional tillage. Rotational cropping means that both conventional and no-tillage systems were under a rotational cropping system. Continuous cropping indicates that both conventional and no-tillage systems were under a continuous cropping system. The cropping systems were a continuous corn (*Zea mays* L.) -wheat (*Triticum aestivum* L.) treatment, and the rotational system was composed of a corn-wheat-soybean [*Glycine max* (L.) Merr.]- wheat (wheat for cover crop only) rotation. Pastureland consisted of bahiagrass (*Paspalum notatum* L.), and woodland consisted of mixed forest. The EVS tillage experiments were started in 1988 with cropland treatments consisting of conventional tillage and no-tillage. The cropping system consisted of corn-soybean rotation with a crimson clover (*Trifolium incarnetum* L.) cover crop every winter until 1996. The cropping system was then changed to ultra-narrow row crop cotton (*Gossypium hirsutum* L.) with black oat (*Avena strigosa* L.) or lupin (*Lupinus albus* L.) cover crop for 2 years. The cropping system was then modified to black oat cover during winter of 1998-1999 and sorghum-sudan grass [Sorghum x drummondii (Nees ex Stend.) Millsp. and Chase] during summer of 1999. The cropping system was then changed to ryegrass (*Lolium perenne* L.) during winter of 1999-2000, sorghum-sudangrass during summer, and black oat during winter of 2000-2001. Pastureland consisted of bermudagrass (*Cynodon dactylon* L.), and woodland consisted of a loblolly pine (*Pinus taeda* L.) plantation.

The treatments were in a completely randomized design with four replications. Soil samples were collected in December 2000, June 2001, and December 2001 at both sites. Samples for Db, SWR, WDC, Ksat, SOC, and TN were taken in June 2001. Samples for WSA and soil strength were taken in December 2000, June 2001, and December 2001. Microbial biomass samples were taken in June, October, and December of 2001.

Field measurements

Bulk density was measured using the core method (Blake and Hartge, 1986). Saturated hydraulic conductivity (K_{sat}) was determined by the borehole method developed by Amoozegar and Warrick (1986). Soil penetrometer measurements were determined using a Rimik® CP 20 recording cone penetrometer (Agridry Rimik Pty Ltd, Queensland, Australia, 4350).

Laboratory measurements

Water stable aggregates were measured using the wet sieving technique (Kemper and Rosenau, 1986). Water dispersible clay was measured using the micropipette method (Soil Survey Laboratory Manual, 1996). Soil water retention at 0.33 and 15 bar tension was determined using a pressure plate (Klute, 1986). The microbial biomass C was measured using the chloroform incubation fumigation method (Alef and Nannipieri, 1995), and soil organic carbon (SOC) and total nitrogen (TN) were determined using dry combustion (Yeomans and Bremner, 1991). Conventional statistics (ANOVA) were used to assess treatment differences, and only differences at the $P = 0.05$ callbacks.

RESULTS AND DISCUSSION

Bulk density

Significant differences in bulk density (Db) existed between treatments at the 0-2 in and 0-6 in depth for both sites (Table 1). At SMRC, Db (0-2 in and 0-6 in) was highest for pastureland and lowest for woodland. No difference for Db existed between no-tillage and conventional tillage systems at the 0-6 in depth. Previous research (Edwards *et al*., 1992) on similar soils found lower Db in the no-tillage treatment than in the conventional systems. Other research (Radcliffe *et al*., 1988) found higher surface Db in the no-tillage *vs*. conventional tillage. At EVS, pastureland had higher Db (0-2 in) followed by no-tillage and conventional tillage systems.

Aggregate stability

Significant differences in % WSA existed at both sites (Table 1). The conventional tillage systems had lower % WSA than the other land use systems at both sites. Our results are generally in agreement with Wood (1977) and Bruce (1990). The WSA were positively correlated with SOC at SMRC and weakly correlated at EVS. Tisdall and Oades (1982) suggested that correlations between SOC and aggregate stability are not always strong because only part of the SOC fraction is involved with aggregate stability.

Soil water retention

Soil water retention was significantly affected by land use at both sites (Table 1). For the SMRC site, the conventional tillage treatments had lower soil water retention than the other land use systems. No significant differences were observed between woodland, rotational cropping- no-tillage, and pastureland treatments. For the EVS site, no-tillage had higher soil water retention than conventional tillage and woodland.

Table 1. Average bulk density, water stable aggregates, and soil water retention as affected by long-term land use within taxonomically similar soils in the Appalachian Plateau and Coastal Plain region of AL.

		Bulk density§		Water stable aggregates¶	Water retention#	
				Depth (in)		
		0-2	0-8	0-2	0-8	
Site†	Land Use‡				0.33bar	15bar
		-----g cm^{-3}-----		---%---	---cm^3 cm^{-3}----	
SMRC	Pastureland	1.44	1.26	52.2	0.21	0.06
	Woodland	1.12	1.13	50.4	0.22	0.08
	Rotational cropping- no tillage	1.43	1.34	49.7	0.21	0.07
	Continuous cropping- no tillage	1.36	1.37	47.2	0.19	0.06
	Rotational cropping- conventional tillage	1.37	1.34	37.7	0.17	0.05
	Continuous cropping- conventional tillage	1.31	1.33	37.3	0.17	0.05
$LSD_{0.05}$		0.078	0.065	4.54	0.02	0.01
EVS	Pastureland	1.49	1.47	36.2	0.13	0.04
	Woodland	1.33	1.46	42.1	0.11	0.03
	No tillage row crop	1.42	1.33	35.1	0.13	0.03
	Conventional tillage row crop	1.4	1.31	31.0	0.12	0.04
$LSD_{0.05}$		0.04	0.06	2.58	0.01	0.006

† SMRC = Sand Mountain Research Center located near Crossville, AL; E.V. Smith Research Unit located near Shorter, AL.

‡ Land use= SMRC: pastureland consisted of bahiagrass, woodland consisted of mixed forest, no-till and conventional tillage systems possessed both continuous corn-wheat and corn-wheat-soybean-wheat in rotation. EVS: pastureland consisted of bermudagrass, woodland consisted of managed loblolly pine plantation, no-till and conventional tillage systems consisted of continuous corn, corn-soybean rotation and cotton cover crops consisted of sorghum-sudangrass during summer 1999, ryegrass during winter of 1999-2000, sorghum-sudangrass during summer 2000 and black oat cover during winter of 2000-2001.

§ bulk density data for June 2001.

¶ water stable aggregates are averaged over three sampling dates.

water retention data for June 2001.

Tollner (1984) found less available water in a no-tillage system, while Mapa (1995) found higher soil water retention in reforested systems. Our forested system is a managed pine plantation at the EVS site, thus our results differ from Mapa (1995).

Water dispersible clay

Significant differences in water dispersible clay existed between treatments at SMRC but not at EVS at the 0-2 in depth (Table 2). The conventional tillage system had higher WDC at SMRC when compared with the other land use systems. For the EVS site, though no significant differences existed between the treatments, no-tillage and conventional tillage treatments had lower WDC than pastureland and woodland at the 0-2 in and 0-8 in depths. These results are in general agreement with Shaw *et al*. (2002), who found WDC to be highly correlated with SOC in sandy coastal plain surfaces dominated by low activity clays.

Hydraulic conductivity

Hydraulic conductivity was highest in woodland and lowest in pastureland at SMRC, while no significant differences were observed in Ksat at EVS between pastureland, woodland, and conventional tillage treatments. Hydraulic conductivity was lowest for the no-tillage system at EVS (Table 2). Our results are in general agreement with Wood (1977).

Soil strength

Analysis of the penetrometer data was confined to the 0-8 in depth. Significant differences in mean soil strength averaged over this depth existed between the treatments at both sites (Table 2). At SMRC, measurements taken in June 2001 showed the highest average cone index existed in the pastureland and no-tillage

Table 2. Average water dispersible clay, Ksat, and soil strength as affected by long-term land use within taxonomically similar soils in the Appalachian Plateau and Coastal Plain region of AL.

Site[†]	Land Use[‡]	Water dispersible clay[§]		Ksat[¶]	Mean soil strength[#]		
		Depth (in)					
		0-2	0-8	0-6	0-8		
					Dec-00	1-Jun	1-Dec
		------%-----		-cm hr^{-1}-	---MPa--	--MPa--	--MPa--
SMRC	Pastureland	53.0	80.0	1.2	nd[††]	2.45	1.63
	Woodland	33.0	66.0	4.7	nd	1.76	1.43
	Rotational cropping- no tillage	48.0	71.0	4.7	1.36	2.21	1.64
	Continuous cropping- no tillage	47.0	64.0	4.0	1.48	2.06	1.79
	Rotational cropping- conventional tillage	69.0	66.0	2.3	1.72	1.44	1.38
	Continuous cropping- conventional tillage	57.0	65.0	2.5	1.84	1.48	1.42
$LSD_{0.05}$		19.2	11.8	2.2	0.32	0.25	0.31
EVS	Pastureland	63.0	66.0	5.1	2.68	2.21	3.09
	Woodland	52.0	55.0	6.7	1.92	2.27	2.69
	No tillage row crop	47.0	47.0	3.0	0. 82	0. 93	0. 84
	Conventional tillage row crop	48.0	50.0	5.6	0.91	1.05	0.70
$LSD_{0.05}$		31.1	22.8	1.9	0.23	0.19	0.35

[†] SMRC= Sand Mountain Research Center located near Crossville, AL; E.V. Smith Research Unit located near Shorter, AL.

[‡] Land use= SMRC: pastureland consisted of bahiagrass, woodland consisted of mixed forest, no-till and conventional tillage systems possessed both continuous corn-wheat and corn-wheat-soybean-wheat in rotation. EVS: pastureland consisted of bermudagrass, woodland consisted of managed loblolly pine plantation, no-till and conventional tillage systems consisted of continuous corn, corn-soybean rotation and cotton cover crops consisted of sorghum-sudangrass during summer 1999, ryegrass during winter of 1999-2000, sorghum-sudangrass during summer 2000 and black oat cover during winter of 2000-2001.

[§] water dispersible clay data for June 2001.

[¶] saturated hydraulic conductivity measurements taken for June 2001.

[#] soil strength measurements taken in December 2000, June 2001, and December 2001.

[††] nd= indicates no data

treatments. At EVS, the highest cone index readings were recorded in the pastureland and woodland. No difference in average cone index existed between no-tillage and conventional tillage at the EVS site.

Soil organic carbon, nitrogen, and soil microbial biomass C

Significant differences existed in SOC and TN between treatments at both sites (Table 3). At SMRC, the no-tillage and pastureland systems had higher SOC (0-2 in) than the conventional tillage systems. At EVS, SOC and TN (0-2 in) were highest for pastureland. The soil organic carbon in the pastureland and no-tillage systems was significantly higher than the conventional tillage system. Our results are in general agreement with Wood (1991) and Reeves (1997), who found decreasing SOC in intensively cultivated soils. Biologically active soil organic carbon is one of the most sensitive indicators of soil quality (Molina, 1994) as it impacts the physical, chemical, and biological processes in soil, and thus provides a relatively rapid measure of the impact of these systems on soil quality (Fenton, 1999).

Soil microbial biomass C was significantly different at both sites for the 0-2 in depth (Table 3). For SMRC, microbial biomass C (0-2 in) was highest for woodland compared to pastureland, no-tillage, and conventional tillage. The conventional tillage system had significantly lower microbial biomass C compared to continuous cropping-no-tillage and pastureland for the SMRC site. These results are in general agreement with Carter (1998) and Saviozzi (2001). At EVS, microbial biomass C (0-2 in) was highest for pastureland compared to woodland, no-tillage, and conventional tillage systems. Similar to the SMRC site, conventional tillage had lower microbial biomass C than no-tillage.

Table 3. Average soil microbial biomass C, soil organic carbon (SOC), and total nitrogen as affected by long-term land use within taxonomically similar soils in the Appalachian Plateau and Coastal Plain regions of AL.

		Microbial biomass C		SOC§		TN¶	
		Depth (in)					
Site†	Land Use‡	0-2	0-8	0-2	0-8	0-2	0-8
		----μg g^{-1}----		-----%-----		-----%-----	
SMRC	Pastureland	170.9	70.3	1.9	1.1	0.05	0.03
	Woodland	252.3	83.9	nd#	2.6	0.13	0.04
	Rotational cropping- no tillage	135.4	79.2	2.0	1.4	0.05	0.03
	Continuous cropping- no tillage	163.1	77.2	2.4	1.3	0.06	0.03
	Rotational cropping- conv. tillage	101.4	53.9	1.2	0.9	0.03	0.02
	Continuous cropping- conv. tillage	62.3	44.6	1.2	1.0	0.03	0.02
$LSD_{0.05}$		39.7	19.0	0.68	0.18	0.09	0.07
EVS	Pastureland	186.4	75.6	2.3	1.2	0.08	0.04
	Woodland	157.3	74	1.4	1.1	0.04	0.03
	No tillage row crop	135.4	90	1.5	1.0	0.05	0.03
	Conventional tillage row crop	79.3	88.6	1.1	0.9	0.03	0.02
$LSD_{0.05}$		24	17.9	0.39	0.25	0.016	0.01

† SMRC= Sand Mountain Research Center located near Crossville, AL; E.V. Smith Research Unit located near Shorter, AL.

‡ Land use= SMRC: pastureland consisted of bahiagrass, woodland consisted of mixed forest, no-till and conventional tillage systems possessed both continuous corn-wheat and corn-wheat-soybean-wheat in rotation. EVS: pastureland consisted of bermudagrass, woodland consisted of managed loblolly pine plantation, no-till and conventional tillage systems consisted of continuous corn, corn-soybean rotation and cotton cover crops consisted of sorghum-sudangrass during summer 1999, ryegrass during winter of 1999-2000, sorghum-sudangrass during summer 2000 and black oat cover during winter of 2000-2001.

§ SOC= soil organic carbon for June 2001.

¶ TN= total nitrogen for June 2001.

nd= indicates no data.

CONCLUSIONS

Lower values of SOC and microbial biomass C in our conventional tillage systems compared to the less cultivated soils suggest decreasing quality that may ultimately lead to a decline in productivity. At EVS, our data suggested that loblolly pine (*Pinus teada* L.) plantation management did not improve soil quality relative to cropland. Our data suggests some ability for no-tillage management to mitigate degradation in agricultural systems, but quality remains below woodland (for SMRC) and pastureland. This may suggest pasture rotations within agricultural cropping systems in no-tillage management to be a sound strategy with regard to soil quality. Our data showed that significant differences in near-surface properties existed for identical soil taxa. These differences were related to the land use system. Variation in near-surface properties that change as a result of land use suggests further work is necessary for developing criteria to enhance soil map unit interpretations.

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